

## OPTIMIZATION OF PLATEN FOR INJECTION MOULDING MACHINE BY GREY RELATIONAL ANALYSIS

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### ABSTRACT

Now a days, injection moulding machine is the most widely used method for conversion of plastics in to different end products - for a wide range of plastic materials to specialty engineering plastic. The role of platen plate in injection moulding machine is very important. In this process, compressive stress occurs at regions. As the load fluctuates at a very fast rate, there is a chance of failure of the tie bar road. Due to heavy size and shape, the weight is increased and also it increases the stress levels at regions, and it is not good for the process. This will create failure of the platen plate and failure of tie road due to stretching by nut and platen. This will create wastage of lots of money, man power, material, time, etc., hence the aim of this case is to study about the major areas like stress effect on tie bar and on platen plate deflection. By gray relational analysis we can optimize the platen for injection molding machine.

**KEYWORDS:** Introduction to Injection Moulding Machine, Design of Experiment, Minitab & Greyrelational Analysis

**Received:** Apr 10, 2017; **Accepted:** Apr 25, 2017; **Published:** May 09, 2017; **Paper Id.:** IJMPERDJUN201715

### INTRODUCTION

The most common method of conversion of plastics is through

- Injection moulding machine
- Compression moulding machine
- Blow moulding machine
- Extrusion and Thermoforming

Among the above listed methods, injection moulding machine is one of the best methods that most of the industries are adopting today.

### COMPONENTS OF PLASTIC INJECTION MOULDING MACHINE

#### Types of Machine

These are broadly classified as plunger and screw types.

- Single-Stage Plunger Machine
- Two-stage Plunger Machine
- Two-stage Screw Plunger Machine
- Reciprocating Screw Type Machine

The complete cycle can be depicted as under:

- Oil is set behind the clamp ram closing the mould. Pressure builds up to develop enough force to keep the mould closed, while the injection process occurs.
- Previously plasticized material, in front of reciprocating screw, is forced into the mould by the hydraulic injection cylinders.
- Pressure is maintained on the material to mould a part free from sink marks, flow marks, welds and other defects.
- At the end of this period, the screw starts to turn plasticizing material for the next shot.
- While this is occurring, the plastic cools in the mould and solidifies to a point, whereby, it can be ejected successfully. This cooling is accomplished by circulating a cooling media, usually water, through drilled holes or channels in mould base, cavities and cores.
- Oil is sent to the return port of clamping ram, separating the mould halves.
- As moving platen returns, the knock-out or ejection mechanism is activated removing pieces from the mould.

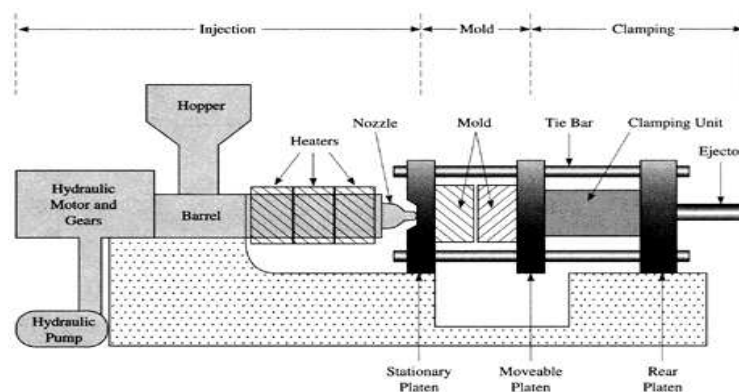


Figure 1: Plastic Injection Moulding Machine

## APPLICATION OF PLASTIC INJECTION MOLDING MACHINE

- In Automobile application like **Radiator Fan, Air Separator.**
- In engineering application like **Pipe End Cap, Pipe Coupler, Textile Bobbin.**
- **Computers & Accessories: Mouse, Key Board Parts.**
- **Electrical & Electronics: 2 point socket, Miracle Base.**
- **Furniture: Back chair with arm.**
- **Food / Non Food Containers: Plastic Container, Round Container.**
- **Medical / Lab: Measuring Cup, Lab Tray.**
- **Writing Instruments / Stationeries: Pen Barrel, Scale.**
- Automotive Structural Parts.

- TV Cabinets.
- Computer Monitor-housing.
- Rigid Packaging Containers.

### THE OBJECTIVES OF THE STUDY ARE AS FOLLOWS

- To minimize stress and deformation with the use of GRA technique.
- To find out the best optimum condition, where there are less stress and low deformation.
- To find out the best combination of all parameters.

### DESIGN OF EXPERIMENT

In this study, the TAGUCHI method was taken to investigate the relation between the response factor and process parameters. MINITAB 16 is also used for optimization and for graphical analysis of the data.

### TAGUCHI METHOD'S CATEGORIES

- Static Problems
- Signals to Noise Ratio

### PARAMETERS CONSIDERATION FOR EXPERIMENT

- **Input Parameters**
  - Hole Size
  - Lateral Distance
  - Linear Distance
- **Output Parameters**
  - Stress
  - Deformation

**Table 1: Range of Process Parameters**

Input Parameters	Level		
	1	2	3
Hole Size	40	42	44
Lateral Distance	250	270	290
Linear Distance	250	270	290

In the present study, the whole size, lateral & linear distance has been selected as input parameters. The range of selected process parameters are shown in Table no 1.

### SELECTION OF ORTHOGONAL ARRAY (OA)

Once, the name has been determined. The orthogonal array selector is shown in Figure 2. The number as subscript in the array designation indicates the number of trials in that array. The total degrees of freedom (DOF) available in an OA

are equal to the number of trials minus one.

		Number of Parameters (P)																				
Number of Levels		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32	L32	L32	L32	L32
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36	L36	L36	L36	L36
	4	L'16	L'16	L'16	L'16	L'32	L'32	L'32	L'32	L'32												
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50										

**Figure 2: The Orthogonal Array Selector**

$$fLn = N - 1$$

Where,

$fLn$  = Total degrees of freedom of an Orthogonal Array

$LN$  = OA designation

$N$  = Number of trials

When a particular OA is selected for an experiment, the following inequality must be satisfied:  $fLn \geq$  Total degree of freedom required for Parameters, and Interactions depending on the number of levels of the parameters and total DOF required for the Experiment, a suitable OA is selected.

**Table 2: The Scheme of L9 Design of Experimental**

Experiment No.	Hole Size	Lateral Distance	Linear Distance
1	40	250	250
2	40	270	270
3	40	290	290
4	42	250	270
5	42	270	290
6	42	290	250
7	44	250	290
8	44	270	250
9	44	290	270

For these parameters, L9 orthogonal have been generated as above, and 9 runs are considered. After generating these runs, the output variables and result of analysis would be generated in Ansys workbench.

## DATA ANALYSIS

The following types of method were used for data analysis.

- ANOVA for S/N data
- S/N response graphs
- Interaction graphs
- Residual graphs

## TESTING RESULTS

After generating runs of all 9 cases, the output variables and result of analysis were generated in Ansys workbench and the results were recorded as shown in the table below.

**Table 3: Experimental Results**

Experiment No.	Hole Size (mm)	Lateral Distance (mm)	Linear Distance (mm)	Stress (MPa)	Deformation (mm)
1	40	250	250	185.36	0.2094
2	40	270	270	183.72	0.2096
3	40	290	290	184.57	0.2098
4	42	250	270	186.01	0.2097
5	42	270	290	185.25	0.2094
6	42	290	250	185.72	0.2097
7	44	250	290	187.06	0.2101
8	44	270	250	184.13	0.2094
9	44	290	270	185.15	0.2108

## Analysis Software MINITAB16

For the given case, MINITSAB is used for the particular problem. The figure shows that the screen view of MINITAB16 software described whole data, which are used in the present study.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
	Hole	Lateral Distance	Linear Distance	Stress	Deflection											
1	40	250	250	185.36	0.2094											
2	40	270	270	183.72	0.2096											
3	40	290	290	184.57	0.2098											
4	42	250	270	186.01	0.2097											
5	42	270	290	185.25	0.2094											
6	42	290	250	185.72	0.2097											
7	44	250	290	187.06	0.2101											
8	44	270	250	184.13	0.2094											
9	44	290	270	185.15	0.2108											

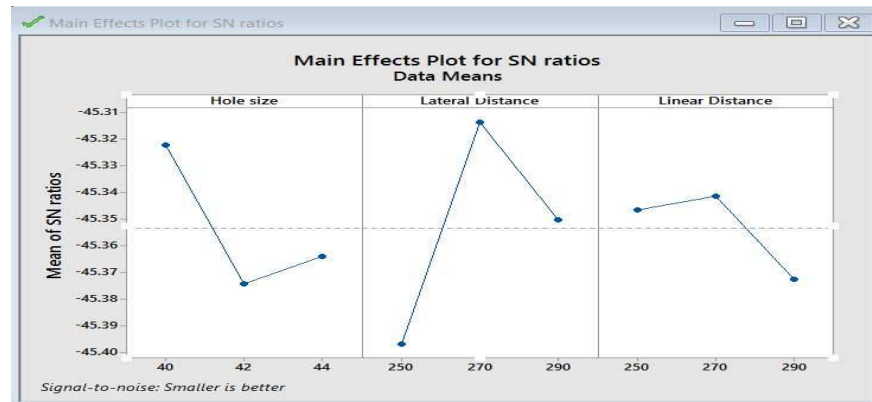
**Figure 3: Screen View of MINITAB16 Software**

## S/N Ratio Calculation for Stress and Deformation

In this, the observed value of Stress and Deformation are transformed in S/N ratio values, to find out the optimum combination of parameters for responding variable. In stress and deformation response —smaller is better— is objective characteristics.

## Main Effects Plot of Stress

The main effects plot for a S/N ratio of stress versatile, Lateral Distance, Linear Distance are shown in the figure, given below:

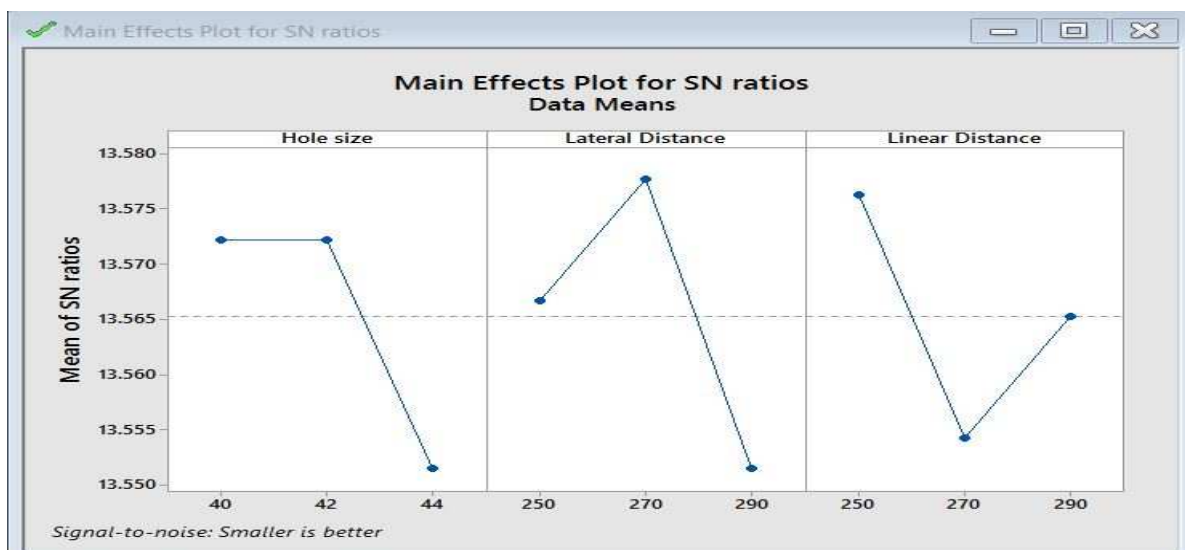


**Figure 4: Effect of Input Parameter on Stress**

- Figure 4 shows that better stress will meet at hole size 42 mm, lateral distance 250 mm and linear distance 290 mm. The graph has been generated by using Minitab-16 statistical software for stress.
- It has been concluded that, the optimum combination of each process parameter for stress will meet at hole size [A2], lateral distance [B1] and linear distance [C3].

## MAIN EFFECTS PLOT OF DEFORMATION

The main effects plot for a S/N ratio of Deformation versus Hole, Lateral Distance, Linear Distance are shown in figure 5



**Figure 5: Effect of Input Parameter on Deformation**

The figure shows that, better Deformation will meet at hole size 44 mm, lateral distance 290 mm and linear distance 270 mm. The graph has been generated by the use of Minitab-16 statistical software for Deformation.

It has been concluded that the optimum combination of each process parameter for deformation will meet at hole size [A3], lateral distance [B3], linear distance [C2].

## S/N RATIO CALCULATION FOR STRESS AND DEFORMATION

Table 4: S/N Ratio Calculation For Stress and Deformation

Experiment No.	Hole Size (mm)	Lateral Distance (mm)	Linear Distance (mm)	Stress (MPa)	Deformation (mm)	S/N Ratio for Stress	S/N Ratio for Deformation
1	40	250	250	185.36	0.2094	-45.3603	13.5805
2	40	270	270	183.72	0.2096	-45.2831	13.5722
3	40	290	290	184.57	0.2098	-45.3232	13.5639
4	42	250	270	186.01	0.2097	-45.3907	13.586
5	42	270	290	185.25	0.2094	-45.3552	13.5805
6	42	290	250	185.72	0.2097	-45.3772	13.568
7	44	250	290	187.06	0.2101	-45.4396	13.5515
8	44	270	250	184.13	0.2094	-45.3025	13.5805
9	44	290	270	185.15	0.2108	-45.3505	13.5226

## GREY RELATIONAL ANALYSIS

## Grey Relational Analysis for Multi Objective Optimization

The purpose of grey relational analysis is, by using GRA technique, the multi-objective problem has been converted into single objective optimization.

## Data Pre-Processing

Normalize the measured values of Surface roughness and Material removal rate ranging from zero to one. This process is known as gray relational normalization. If the target value of original sequence is infinite, then it has a characteristic of “the larger the better” then, the original sequence can be normalized as follows

$$X_i(k) = \frac{y_i(k) - \min y_i(k)}{\max y_i(k) - \min y_i(k)} \quad (1)$$

If the expectancy is “the smaller the better” then, the original sequence should be normalized as follows:

$$X_i(k) = \frac{\max y_i(k) - y_i(k)}{\max y_i(k) - \min y_i(k)} \quad (2)$$

Here,  $X(k)$  I am the value after gray relational generation,  $\min y(k)$  I am the small value of  $y(k)$  me for the quiet response, and  $\max y(k)$  I am the large value of  $y(k)$  me for the quiet response. An ideal sequence is  $(1, 2, 3, \dots, 30) 0 \times k$ ,  $k =$  for the responses. The definition of grey relational grade in the course of grey relational analysis is to reveal the degree of relation between the 30 sequences,  $(1, 2, 3, \dots, 30) 0 \times k$  and  $x_k$ ,  $k = i$ .

## Gray Relational Coefficient and Gray Relational Grade

For ideal and actual experimental results a gray relational coefficient is calculated for the particular relationship.

$$\zeta_i(k) = \frac{\Delta \max + \psi \Delta \max}{\Delta o_i(k) + \psi \Delta \max}$$

The gray relation grade is defined as follows

$$\gamma_i = \frac{1}{n} \sum_{k=1}^n \zeta_i(k)$$

## NORMALIZATION OF EXPERIMENTAL RESULTS

Normalization of stress and deformation is done between 0 and 1. Here, for stress and deformation, normalization equation 'smaller-the-better', 'larger-the-better' is used as shown in Table 5

**Table 5: Data Pre-Normalization**

Exp. No.	Data Pre-Normalization	
	Stress	Deformation
1	0.4932	0
2	0	0.1433
3	0.2562	0.2867
4	0.6875	0.2158
5	0.4607	0
6	0.6012	0.2158
7	1	0.5008
8	0.1239	0
9	0.4306	1

### Find the Normalised SN Ratio

There are totally 9 experiments and find two response.

- Normalised SN ratio.

For stress:

$$\begin{aligned} \text{Exp (1): Formula} &= \frac{\text{Max.value} - (-\text{Select value one by one 1 to 9})}{\text{Max.value} - \text{Min.value}} \\ &= \frac{-45.2831 - (-45.3603)}{-45.2831 - (-45.4396)} \\ &= 0.4932 \end{aligned}$$

$$\begin{aligned} \text{Exp (2):} &= \frac{-45.2831 - (-45.2831)}{-45.2831 - (-45.4396)} \\ &= 0 \end{aligned}$$

For deformation: (same formula as per stress)

$$\begin{aligned} \text{Exp (1):} &= \frac{13.5805 - 13.5805}{13.5805 - 13.5226} \\ &= 0 \end{aligned}$$

$$\begin{aligned} \text{Exp (2):} &= \frac{13.5805 - 13.5722}{13.5805 - 13.5226} \\ &= 0.1433 \end{aligned}$$



## DEVIATION SEQUENCES

To find out grey relational coefficient, one has to calculate deviation sequence using equation.

$$\Delta_{oi} = |X_o(k) - X_i(k)|$$

**Table 6: Deviation Sequences**

Exp. No	Deviation Sequence	
	Stress	Deformation
1	0.5068	1
2	1	0.8567
3	0.7438	0.7133
4	0.3125	0.7842
5	0.5393	1
6	0.3988	0.7842
7	0	0.4992
8	0.8762	1
9	0.5694	0

- Deviation Sequences

Same formula for both stress and deformation

**Formula:** Max.value – (select value one by one 1 to 9)

For stress:

**Exp (1):** = 1- 0.4932 = 0.5068

**Exp (2):** = 1-0 = 1

**Exp (3):** = 1-0.2562 = 0.7438

(Same for the deformation)

## CALCULATION OF GREY RELATIONAL COEFFICIENT AND GREY RELATIONAL GRADE

The grey relational coefficient is used to express the relationship between the ideal and normalized experimental results

**Table 7: Calculation of Grey Relational Coefficient & Grey Relational Grade**

Exp. No	Grey Relational Coefficient		Grey Relational Grade
	Stress	Deformation	
1	0.4966	0.3333	0.41495
2	0.3333	0.3685	0.3509
3	0.4019	0.412	0.40695
4	0.6153	0.3893	0.5023
5	0.481	0.3333	0.40715
6	0.5562	0.3893	0.47275
7	1	0.5004	0.7502
8	0.3633	0.3333	0.3583
9	0.4675	1	0.73375

- Grey relation coefficient (GRC)

Formula: same for both stress and deformation

$$\frac{\text{Min. value} + (0.5 \times \text{Max. value})}{(\text{select value one by one 1 to 9}) + (0.5 \times \text{Max. value})}$$

For stress:

$$\text{Exp (1):} = \frac{0 + (0.5 \times 1)}{0.5068 + (0.5 \times 1)} = 0.4966$$

$$\text{Exp (2):} = \frac{0 + (0.5 \times 1)}{1 + (0.5 \times 1)} = 0.3333$$

(Same for the deformation).

- Grey relational grade (GRG)

**Formula:** Same for both stress & deformation.

- Select the one by one value of the GRC to find the GRG.
- First step:
- Take the first value of the stress & first value of the deformation from the GRC.

$$\text{Exp (1):} = \frac{0.4966 + 0.3333}{2} = 0.41495$$

$$\text{Exp (2):} = \frac{0.3333 + 0.3685}{2} = 0.3509$$

$$\text{Exp (3):} = \frac{0.4019 + 0.412}{2} = 0.40695$$

In the GRG, the higher value of the GRG is the optimal solution and optimal parameter of our Case. In a gray relational analysis, the total performance of multi objective optimization is depending on the value of the gray relational grade. According to the performed experiment design, it is clearly observed that table experiment no 7<sup>th</sup> has the highest grey relation grade. Thus, the 7<sup>th</sup> experiment gives the best multi performance characteristics among the 9 experiments.

**Table 8: Main Effect of Factors on Gray Relational Grade**

Control Factor	Level 1	Level 2	Level 3
Hole size	0.39093333	0.46073333	<b>0.61075</b>
Lateral distance	<b>0.55581667</b>	0.36878333	0.53781667
Linear distance	0.412	0.52898333	<b>0.52943333</b>

As we know that higher gray relational grade value will give optimum value of stress and deformation. Thus, it is revealed that response will be optimized at hole size 44 mm, lateral distance 250 mm and linear distance 290 mm.

## RESULTS AND DISCUSSIONS

In this paper, the combined approach of Taguchi and GRA is discussed, after the nine experiments were carried out of platen for the Taguchi selected array. From the result of integrity analysis and GRA, it can be concluded that case 7 which has hole size 44mm, lateral distance 250mm, linear distance 290mm gives the nominal Stress, Deformation of the platen is there and this combination can be utilized to optimize platen.

### Optimized Results Based on Factor Level for Prediction on GRA

Table 9

Hole size (mm)	Lateral distance (mm)	Linear distance (mm)	Stress (Mpa)	Deformation (mm)
44	250	290	187.06	0.2101

## CONCLUSIONS

In these three parameters i.e. hole size, lateral distance, linear distance, material removal from platen was analysed for. Taguchi method was used in this study to experiment and determine the optimum parameter settings that affect the output characteristic responses such as stress and deformation, as proposed in the study.

Optimization of all responses had been carried out with the help of Grey relation method. The higher grey relational grade value would give optimum value of stress and deformation. It has been found that, response optimisation will be at hole size 44 mm, lateral distance 250 mm and linear distance 290 mm.

## ACKNOWLEDGEMENTS

Authors are Greatful To Windsor Machines Limited For Providing useful guidance in this particular case.

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